Search For Twisted Polarization in Arcsecond Scale Quasar Jets

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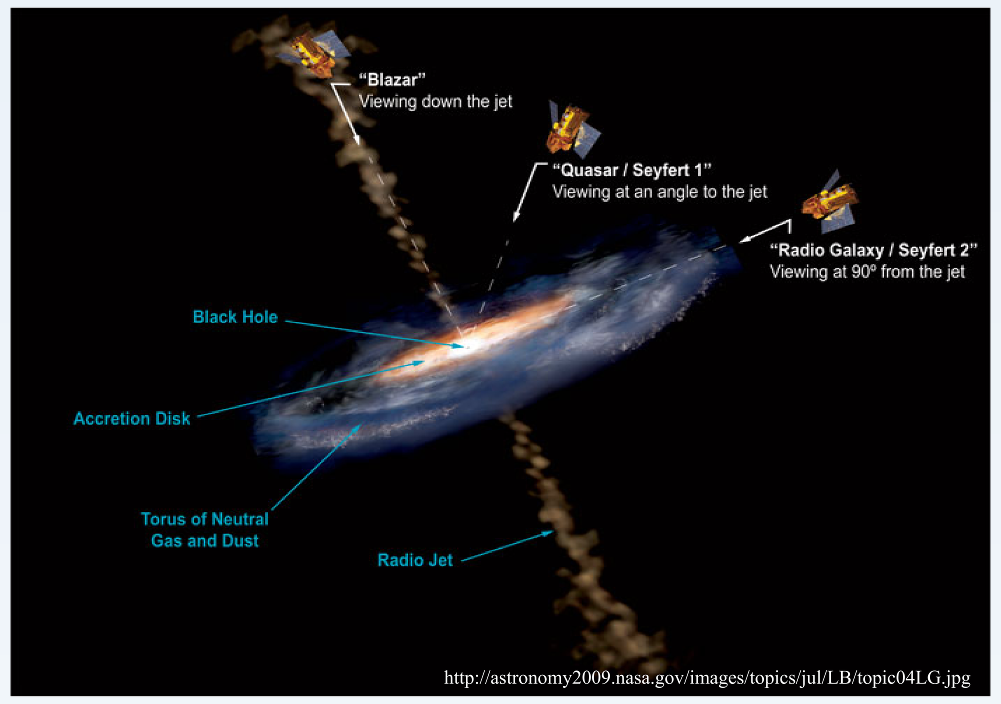
Abstract

The quasar 3C345 displays a seemingly singular 35 degree twist in the polarization of its kiloparsec-scale jet. Because of the vast number of quasars known, it seems unlikely that 3C345 is alone in this respect. By imaging quasars identified as having structure by Murphy, Brown & Perley (1993), and by Perley (1982), and by sampling sources from the VLA calibrator manual, we hope to find additional examples of this property that could help us to better understand the nature of quasar jets.

Background

While black holes themselves are invisible, matter such as stars and gas falling towards the a black hole's event horizon is heated so much that it turns into plasma and is bright at all wavelengths. Sometimes, jets of this material are shot out in two directions, often at a large fraction of the speed of light. Such black holes are known as Quasars (Quasi Stellar Radio Sources) because they were first seen as points like stars, but later discovered to be extragalactic. The bright core of a quasar can be 10-10,000 times the Schwartzchild radius of the black hole itself—roughly a few trillion kilometers. Their jets can stretch far out of the galaxy that contains the quasar.



Above is an artist's depiction of a quasar. The black hole itself is invisibly small, but the accretion disk of in-falling matter, through mechanisms currently unknown, creates two jets of plasma moving at relativistic speeds. At certain angles, the quasar is obscured by a torus of dust. One jet is pointing at some angle towards us, boosted due to relativistic effects, and the opposite jet pointing away is dimmed, so often we only see one jet.

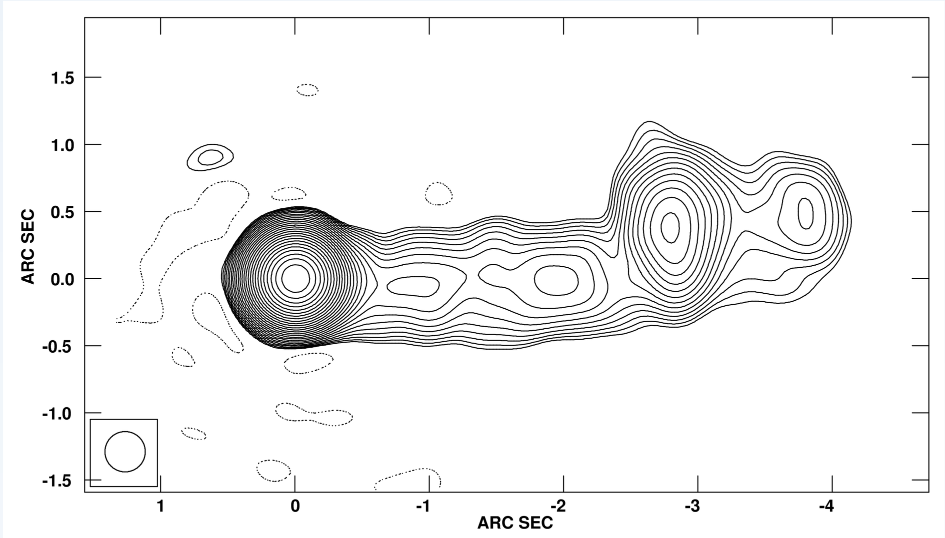
Our equipment

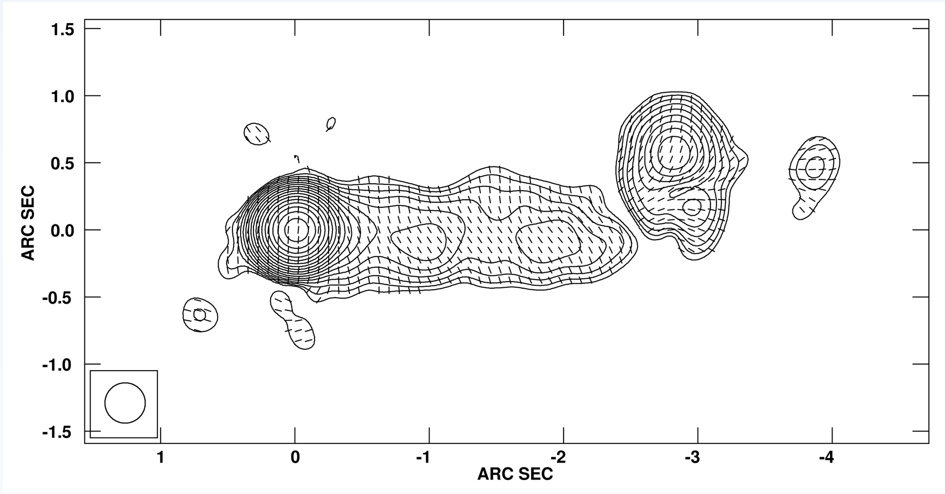
The Very Large Array (VLA) in New Mexico is the premier radio observatory in the world. It contains 27 antennas (think giant satellite dishes), each 25 meters in diameter. This gives 351 pairs of antennas, the outputs of which are mixed digitally to produce Fourier components of the brightness of the sky. These signals are then combined by Fourier transform, a process known as Aperture synthesis, to produce an image. The image produced will have the same angular resolution of a single telescope with the diameter of the entire array. The VLA antennas can be moved into different configurations, but

the greatest detail comes from A array, which has a diameter of 42 kilometers.

The VLA archive (archive.nrao.edu) provides public use of data for download. We identify and flag bad data, calibrate them, and make maps of quasars using the AIPS and DIFMAP software.

3C345





Intensity contour maps are analogous to elevation maps of terrain—the more contours the brighter the source in a given area. The top map shows total intensity and the bottom map shows polarized intensity. The tick marks on the bottom map indicate the direction of the electric field from the radiation. Arcseconds are the measure of the space taken up in the sky that is taken up by the source. The farther away an object is, the larger distance one arcsecond corresponds to, which is usually measured in parsecs (1 parsec = 3.26 ly). 3C345 has a redshift z=0.595, so from cosmology we calculate a scale of 6.64 kpc/".

3C345 is roughly 4 arcseconds across, so its projected length is 27 kpc = 86 light years. The image shown is at C band (4.86 GHz, 6.2 cm). The anomalous twist in the polarization of the jet of 3C345 has sparked the search for more sources displaying this feature. Calculations by Professors Roberts & Wardle suggest that the twist in polarization is indicative of a helical magnetic field. It also provides a unique way to measure the speed of the jet on a kiloparsec scale which gives a surprisingly high speed of 0.98c.

Our Results

Source: 0106+013, 8.4 kpc/" scale

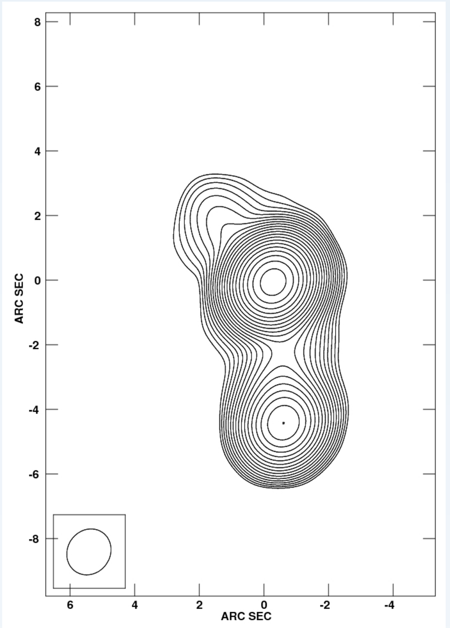


Fig. 1

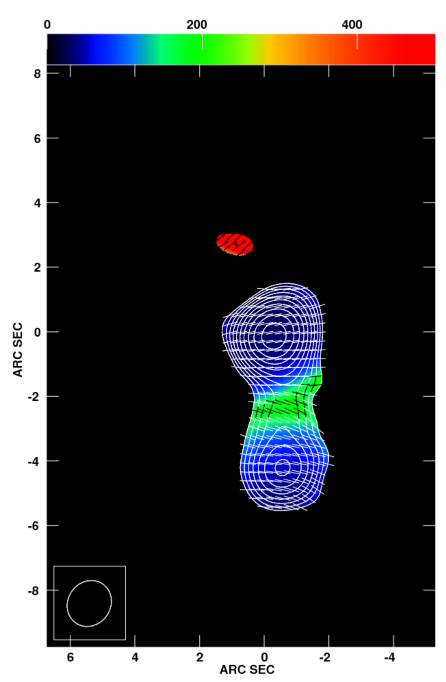


Fig. 2

L band (1.425 GHz, 21 cm)

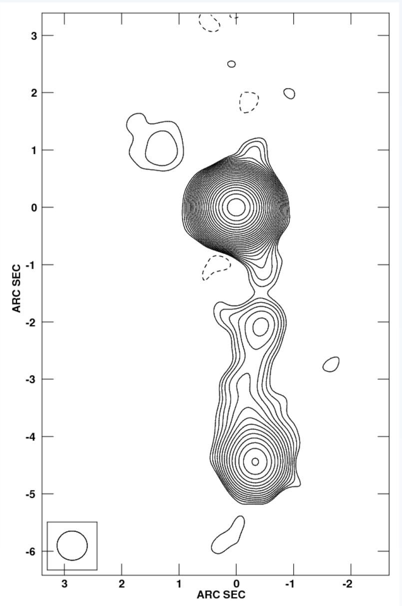


Fig. 3

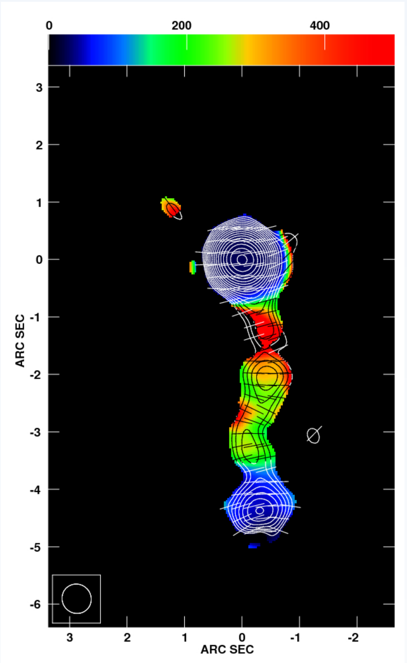


Fig. 4

C band (4.85 GHz, 6.2 cm)

The images on the left show total intensity. The images on the right show polarized intensity. Tick marks indicate the direction of the electric field, and color indicates the fractional polarization (polarized flux / total flux).

Source: 0504+030, 8.2 kpc/" scale

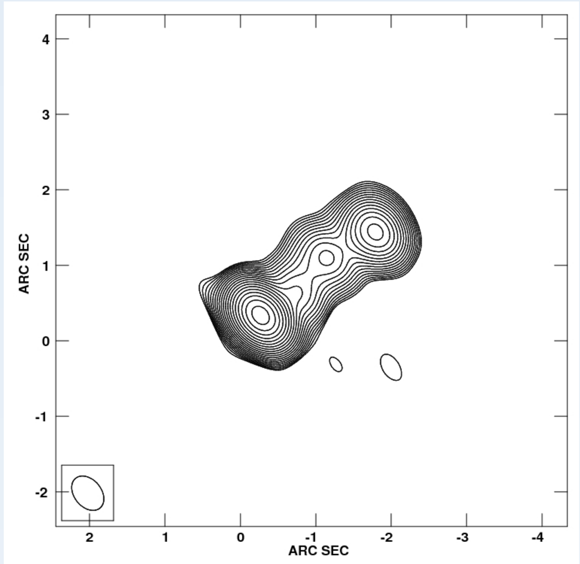


Fig. 5

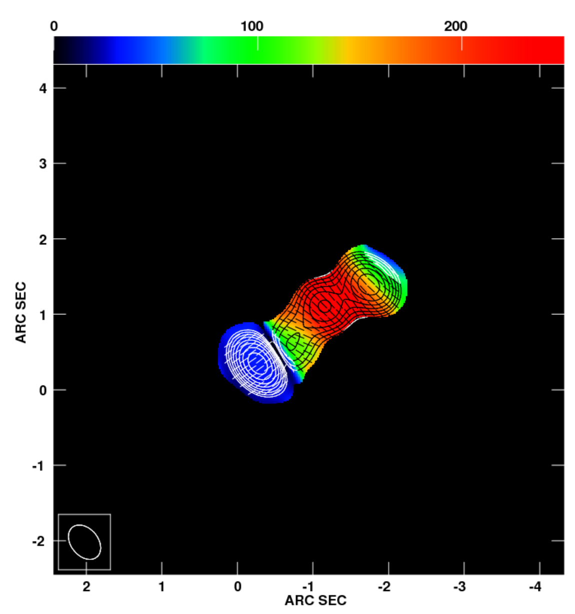


Fig. 6

C band (4.86 GHz, 6.2 cm)

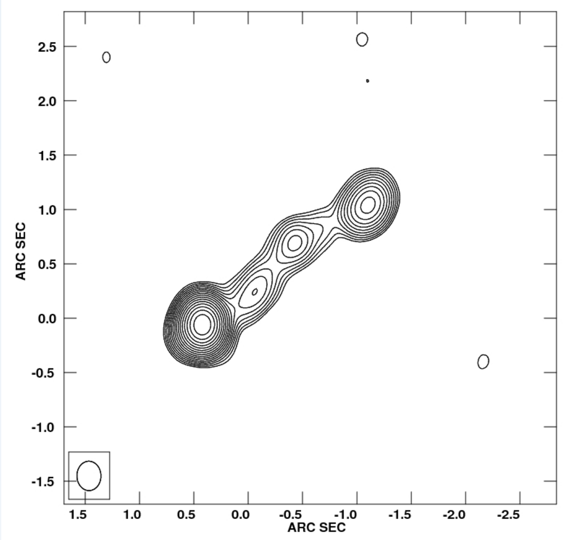


Fig. 7

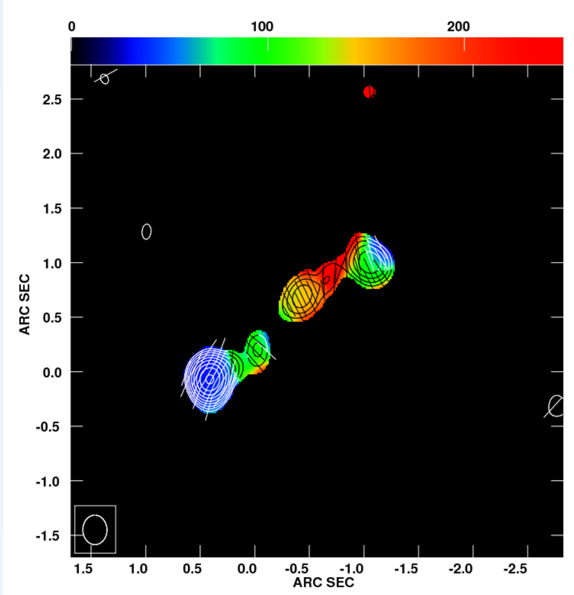


Fig. 8

X band (8.25 GHz, 3.6 cm)

As we can see in 0106+013 (fig. 1-4) and 0504+030 (fig. 5-8), there is an apparent twist in the polarization at the lower frequency (tick marks are neither along nor across the jet in fig. 2,6). In the higher frequency map, the jet itself is curving and the polarization follows it (fig. 4,8). Thus, neither is an analog of 3C345.

Conclusion

Having imaged 136 sources and made 59 additional follow-up maps at other frequencies, we have found no other examples of a twisted polarization in a quasar jet. The search will continue in fall 2012. If analogs of 3C345 are discovered, they will be observed in more detail with the newly-refurbished VLA.